

TITLE OF THE INVENTION

CALIBRATION PATTERN UNIT

CROSS-REFERENCE TO RELATED APPLICATIONS

5 This application is based upon and claims the
benefit of priority from the prior Japanese Patent
Application No. 2002-251634, filed August 29, 2002,
the entire contents of which are incorporated herein by
reference.

BACKGROUND OF THE INVENTION

10 1. Field of the Invention

The present invention relates to a calibration
pattern unit which is used to obtain correction
information of an imaging system.

2. Description of the Related Art

15 Various calibration patterns used to obtain
correction information of the imaging system have
conventionally been presented. For example, Jpn.
Pat. Appln. KOKAI Publication No. 11-166818 presents
a technology for using a calibration pattern in which
20 a known geometric pattern is drawn on a flat plate, and
obtaining correction information of an imaging system
by changing a relative distance between the pattern and
the imaging system. Jpn. Pat. Appln. KOKAI Publication
No. 2001-82941 presents a technology for constituting
25 a calibration pattern by describing similar geometric
patterns on surfaces of a corner cube structure, and
obtaining correction information of an imaging system.

BRIEF SUMMARY OF THE INVENTION

According to a first aspect of the present invention, there is provided a calibration pattern unit which obtains correction information of an imaging system by imaging at the imaging system, the unit comprising:

5 a calibration pattern in which a predetermined pattern is formed on one of a plurality of three-dimensionally arranged planes and one or more curved surfaces; and

10 a relative position and posture fixing section which fixes relative position and posture between the calibration pattern and the imaging system.

According to a second aspect of the present invention, there is provided a calibration pattern unit which obtains correction information of an imaging system by imaging at the imaging system, the unit comprising:

15 one of a plurality of three-dimensionally arranged planes and one or more curved surfaces; and

20 a calibration pattern in which a predetermined pattern is formed on the one of a plurality of three-dimensionally arranged planes or one or more curved surfaces and in a range where a shape is substantially similar to an object imaged by the imaging system.

25 According to a third aspect of the present invention, there is provided a calibration pattern unit

which obtains correction information of an imaging system by imaging at the imaging system, the unit comprising:

5 a calibration pattern in which a predetermined pattern is formed on one of a plurality of three-dimensionally arranged planes and one or more curved surfaces; and

an imaging area instruction section configured to instruct an area to be imaged when the calibration
10 pattern is imaged.

According to a fourth aspect of the present invention, there is provided a calibration pattern unit which obtains correction information of an imaging system by imaging at the imaging system, the unit
15 comprising:

a calibration pattern in which a predetermined pattern is formed on one of a plurality of three-dimensionally arranged planes and one or more curved surfaces; and

20 an imaging posture instruction section configured to instruct a posture of the imaging system with respect to the calibration pattern.

Advantages of the invention will be set forth in the description which follows, and in part will be
25 obvious from the description, or may be learned by practice of the invention. Advantages of the invention may be realized and obtained by means of the

instrumentalities and combinations particularly pointed out hereinafter.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The accompanying drawings, which are incorporated
5 in and constitute a part of the specification,
illustrate embodiments of the invention, and together
with the general description given above and the
detailed description of the embodiments given below,
serve to explain the principles of the invention.

10 FIG. 1 is a view illustrating a calibration
pattern;

FIG. 2 is a perspective view showing a calibration
pattern unit according to a first embodiment of the
present invention;

15 FIG. 3 is a view showing an appearance of
a calibration pattern of the calibration unit of
the first embodiment observed through a finder of
an imaging system;

FIG. 4 is a view showing a calibration pattern
20 unit according to a second embodiment of the present
invention;

FIG. 5 is a modification example of the
calibration pattern unit of the second embodiment;

FIG. 6 is a perspective view showing a calibration
25 pattern unit according to a third embodiment of the
present invention;

FIG. 7 is a view showing a first modification

example of the calibration pattern unit of the third embodiment;

FIG. 8 is a view showing a second modification example of the calibration pattern unit of the third
5 embodiment;

FIG. 9 is a view showing a calibration pattern unit according to a fourth embodiment of the present invention;

FIG. 10 is a view showing a first modification example of the calibration pattern unit of the fourth
10 embodiment;

FIG. 11 is a view showing a second modification example of the calibration pattern unit of the fourth embodiment;

FIG. 12 is a view showing a third modification example of the calibration pattern unit of the fourth
15 embodiment;

FIG. 13 is a view showing a fourth modification example of the calibration pattern unit of the fourth
20 embodiment;

FIG. 14 is a perspective view showing a calibration pattern unit according to a fifth embodiment;

FIG. 15 is a view showing a modification example of the calibration pattern unit of the fifth
25 embodiment;

FIG. 16 is a view showing a configuration of an imaging section of a calibration device to which

a calibration pattern unit of a sixth embodiment of the present invention is applied;

FIG. 17 is a view showing an image of a calibration pattern observed through a finder of an imaging system in the imaging section of the configuration of FIG. 16;

FIG. 18 is a view illustrating a portion corresponding to the image shown in FIG. 17 on the calibration pattern unit;

FIG. 19 is a view showing the calibration pattern unit of the sixth embodiment;

FIG. 20 is a view showing a first modification example of the calibration pattern unit of the sixth embodiment;

FIG. 21 is a view showing a second modification example of the calibration pattern unit of the sixth embodiment;

FIG. 22 is a view showing a third modification example of the calibration pattern unit of the sixth embodiment;

FIG. 23 is a view showing a fourth modification example of the calibration pattern unit of the sixth embodiment;

FIG. 24 is a view corresponding to FIG. 19 when an imaging instruction section corresponding to both images of the observed calibration pattern shown in FIG. 17 is disposed;

FIG. 25 is a view corresponding to FIG. 20 when an imaging instruction section corresponding to both images of the observed calibration pattern shown in FIG. 17 is disposed;

5 FIG. 26 is a view corresponding to FIG. 21;

FIG. 27 is a view corresponding to FIG. 22 when an imaging instruction section corresponding to both images of the observed calibration pattern shown in FIG. 17 is disposed;

10 FIG. 28 is a view corresponding to FIG. 23 when an imaging instruction section corresponding to both images of the observed calibration pattern shown in FIG. 17 is disposed; and

FIG. 29 is a view corresponding to FIG. 23 when
15 an imaging instruction section corresponding to both images of the observed calibration pattern shown in FIG. 17 is disposed.

DETAILED DESCRIPTION OF THE INVENTION

Before each embodiment of a calibration unit
20 of the present invention is described in detail, explanation will be made of an example of a known geometric pattern which is a predetermined pattern drawn on a calibration pattern of the calibration pattern unit. The example of the known geometric
25 pattern is common to all the embodiments.

That is, as shown in FIG. 1, a known geometric pattern constituted of pluralities of large and small

black circles 1 and 2, a surface crossline 3 and
an outer boundary line 4 is drawn on three flat plate
calibration pattern drawn sections to constitute
a calibration pattern 5. The large and small black
5 circles 1, 2, the surface crossline 3 and the outer
boundary line 4 constituting the known geometric
pattern, i.e., pattern components, are drawn at
constant intervals by a certain rule. The intervals
and the rule can be optionally selected depending on
10 necessary imaging system correction information, and
the invention imposes no restrictions. For example,
the black circle may be a cross mark or a black and
white double circle. The black circles may be
differentiated from each other by color information in
15 place of size. The surface crossline 3 and the outer
boundary line 4 may be broken lines. Additionally,
there are no specific restrictions on areas. The
calibration pattern drawn section may be a curved
surface or a combination of a plurality of planes
20 other than three.

In the drawings referred to in the following
description of each embodiment, a known geometric
pattern similar to the above is actually drawn on
the calibration pattern drawn section. However, to
25 simplify the drawings, only a place of a surface where
the known geometric pattern is drawn is shown by
hatching when necessary. This hatched surface is set

as a pattern drawn surface.

The entire calibration pattern where such a known geometric pattern is drawn is represented by a calibration pattern 5, 5-1, 5-2 or the like common to
5 all the embodiments. Further, in an example shown in FIG. 1, a calibration pattern 5 has a corner cube shape, which is not limitative of a shape in each of the following embodiments. In the example of FIG. 1, the known geometric pattern is drawn on an inner wall
10 surface of the corner cube shape. However, the pattern may be drawn on an outer wall surface in accordance with an imaging angle.

As the imaging system of the invention to carry out calibration, various imaging systems such as a film
15 camera, a digital camera, a video camera, a microscopic endoscope, a multiple-lens stereo camera, a pattern projection camera and a slit scan camera are available, and there are no restrictions on types.

Next, the preferred embodiments of the present
20 invention will be described with reference to the accompanying drawings.

[First Embodiment]

As shown in FIG. 2, in a calibration pattern unit of a first embodiment of the present invention, an
25 imaging system 6 is controlled in position and posture with respect to a calibration pattern 5-1 by a relative position and posture fixing section 7. The relative

position and posture fixing section 7 may be completely fixed to the calibration pattern 5-1, or detachably attached by a screw or the like. An adjustment mechanism such as a camera platform may be installed to deal with fine adjustment of a position and a posture, and mounting of a plurality of imaging systems. Any degree of adjustment freedom may be provided as long as a position and a posture which have been defined are held by a fixture such as a screw after all.

In the calibration unit of such a configuration, when the calibration pattern 5-1 is observed through a not-shown finder of the imaging system 6, an image 8 similar to that shown in FIG. 3 is obtained.

Good calibration pattern imaging depends on calibration intension, a shape of the calibration pattern, and a situation of an imaging environment or the like. Normally, there are optimal values for a position of a boundary line for carrying out good calibration, a size of a point to be observed, an observation direction of the boundary line, an area size where a pattern drawn surface is imaged etc. These are control conditions after all for imager magnification and an imaging angle, i.e., position and posture between the calibration pattern 5-1 and the imaging system 6, when the calibration pattern 5-1 is imaged by the imaging system 6. A mechanism of the relative position and posture fixing section 7 is set

to satisfy these conditions. Thus, by installing the imaging system 6 on the relative position and posture fixing section 7 disposed on the calibration pattern 5-1, an operator can carry out good calibration pattern imaging without being bothered by adjustment each time.

[Second Embodiment]

Next, a second embodiment of the present invention will be described. A calibration pattern unit of the second embodiment is used to calibrate an imaging system so that good imaging can be carried out by the imaging system which images a real cylindrical object.

Thus, as shown in FIG. 4, the calibration pattern unit of the second embodiment has a calibration pattern 5-2 which is substantially similar in shape and size to the real object. That is, a ratio between the calibration pattern 5-2 and the object image by the imaging system in width (W), height (H) and depth (D) is set to 1.0. The calibration pattern 5-2 is imaged under conditions similar to imaging magnification and angle conditions when the real object is actually imaged.

That is, for example, for the purpose of three-dimensionally reconfiguring the real object, calibration imaging is carried out by using a calibration pattern which has such a roughly similar shape. Accordingly, it is possible to obtain known point coordinate information in a tree-dimensional

space corresponding to an image space to be corrected
at minimum. Therefore, a load of calibration
calculation can be reduced and, at the same time,
highly accurate calibration data from which unnecessary
5 points easily including noise are removed can be
obtained.

FIG. 5 is a view showing a modification example of
the calibration pattern unit of the second embodiment
of the present invention. That is, the calibration
10 pattern unit of the modification example has a
calibration pattern 5-3 which has a surface shape based
on an average human face shape to match imaging carried
out to three-dimensionally reconfigure a human face.

As in the case of the second embodiment, by
15 executing calibration imaging under imaging conditions
similar to those of image magnification, an imaging
angle etc., to image a real human, calibration
pattern imaging best suited to three-dimensional
reconfiguration of the human face is carried out.

20 [Third Embodiment]

Next, a third embodiment of the present invention
will be described. As shown in FIG. 6, a calibration
pattern unit of the third embodiment is configured by
describing a calibration pattern 5-4 on a surface of a
25 part of a bowl-shaped, i.e., roughly spherical surface.

In this case, a pattern point-symmetrical
nearly to a center of the surface is drawn as shown.

Accordingly, if imaging of the calibration pattern 5-4 is tried nearly at a center of a field angle of an imaging system which carries out calibration, it is possible to carry out good and always uniform calibration imaging without little dependence on an imaging direction.

Each of FIGS. 7 and 8 is a view showing a modification example of the calibration pattern unit of the third embodiment. Here, the first modification example of FIG. 7 is a calibration pattern unit which comprises a calibration pattern 5-5 having a known geometric pattern drawn on each surface of a regular dodecahedron. The second modification example of FIG. 8 is a calibration pattern unit which comprises a calibration pattern 5-6 having a known geometric pattern drawn on each surface of a regular dodecahedron.

According to the modification examples, as in the case of the third embodiment, nearly uniform calibration pattern observation can be carried out without any dependence on an imaging direction of the calibration pattern, and a calibration pattern constituted geometrically easily can be formed.

As shown by the third embodiment, and the first and second modification examples thereof, various modifications can be made of the embodiment. As other polyhedrons to be used, there are a regular

tetrahedron, a regular hexahedron, an elliptic ball,
a polyhedron combining parts thereof or a plurality of
regular polyhedrons of a kind, a polyhedron combining
a plurality of regular polyhedrons of different kinds,
5 and a polyhedron having a pattern drawn not on an outer
wall surface but on an inner wall surface. Thus, there
are no restrictions on shapes.

[Fourth Embodiment]

Next, a fourth embodiment of the present invention
10 will be described.

If the calibration pattern 5 of the corner
cube type shown in FIG. 1 is imaged well, a result
becomes similar to that shown in FIG. 3. In this case,
if a boundary of an area included in a field angle is
15 drawn, a result becomes similar to that shown in
FIG. 9. Thus, in a calibration pattern unit of the
fourth embodiment, a boundary line 9 is drawn in an
actual imaging instruction section on a calibration
pattern 5-7.

20 Thus, when imaging is carried out by an imaging
system, the imaging instruction section (boundary line
9) adjusts position and posture between the imaging
system and the calibration pattern 5-7 to carry out
imaging fully through a not-shown finder of the imaging
25 system. Therefore, it is possible to carry out ideal
calibration pattern imaging.

Various modifications can be made of the fourth

embodiment. For example, in a first modification
example of FIG. 10, an area itself where a calibration
pattern 5-8 is drawn is set as an imaging instruction
section. By such a configuration, a minimum necessary
5 pattern is drawn in an area to be imaged.

As shown in FIG. 11, a second modification example
is that a boundary of a calibration pattern 5-9 is a
boundary of a structure of a calibration pattern unit,
constituting an imaging instruction section. By such
10 a configuration, a calibration pattern unit having
a minimum necessary size can be constituted, and it
is possible to provide a calibration pattern unit
excellent in transportation and storage.

FIG. 12 is a view showing a third modification
15 example. That is, the inside and the outside of
a calibration pattern 5-9 are colored differently to
constitute an imaging instruction section. It is
possible to provide a highly recognizable imaging
instruction section.

20 As shown in FIG. 13, a fourth modification example
is a calibration pattern unit where so-called "register
marks" 9-1 to 9-6 are drawn on a calibration pattern
5-10 at parts of a boundary line 9, e.g., at corners of
the boundary line, to constitute an imaging instruction
25 section. In such a calibration pattern unit, the
imaging instruction section can be drawn to be easily
recognized in a minimum necessary area.

Various shapes can be employed for the imaging instruction section, and there are no restrictions on the shape.

[Fifth Embodiment]

5 Next, a fifth embodiment of the present invention will be described. As shown in FIG. 14, the fifth embodiment provides a calibration pattern unit where a bar-shaped imaging instruction section 10 is installed at a corner of a calibration pattern 5-11
10 drawn on an inner wall surface of a corner cube shape. This imaging instruction section 10 instructs an optical axis of a not-shown imaging system. That is, the imaging instruction section 10 is installed with respect to the calibration pattern 5-11 so that by
15 matching the imaging instruction section 10 preset in direction with the optical axis of the imaging system, the calibration pattern 5-11 can be imaged as a nearly uniform pattern distribution around the optical axis.

 An operator pays attention so that the imaging
20 instruction section 10 can be observed substantially as a point while observing the bar-shaped imaging instruction section 10 through a not-shown finder of the imaging system, and carries out imaging so that the imaged calibration pattern 5-11 can be set within
25 a proper field angle. Accordingly, the calibration pattern can be imaged in a proper imaging direction where a rotational direction component around the

optical axis is removed.

By referring to FIG. 15, a first modification example of the fifth embodiment of the present invention will be described. FIG. 15 shows a surface cut out of the calibration pattern 5-11 of the corner cube type shown in FIG. 14. That is, this surface is constituted of two platelike calibration patterns 5-11-A and 5-11-B. A hole 5-11-A-1 is bored at least on a part of the calibration pattern 5-11-A. A black elliptic shape 5-11-B-1 is drawn in a position on the calibration pattern 5-11-B observable through the hole 5-11-A-1 from a predetermined imaging position 11. Such a configuration is set for all the drawn surfaces of the corner cube type calibration pattern.

When the calibration unit of the above configuration is used, the calibration pattern is imaged while a position and a posture of a not-shown imaging system are adjusted so that the black elliptic pattern can be imaged best as a whole when the imaging is carried out from the predetermined imaging position 11. Thus, it is possible to instruct an imaging position and a posture most suited to calibration pattern imaging.

[Sixth Embodiment]

Next, a sixth embodiment of the present invention will be described by referring to FIGS. 16 to 19.

The embodiment provides a calibration pattern unit used by a calibration device which has an imaging

section similar to that shown in FIG. 16. That is,
in the imaging section, a stereo optical system
constituted of four flat mirrors 12-1, 12-2, 12-3, 12-4
is set in a predetermined position with respect to
5 an imaging system 13. Here, a position and posture
relation between the stereo optical system and the
imaging system 13 is fixed by a not-shown member for
fastening.

For example, when a calibration pattern similar
10 to that shown in FIG. 18 is imaged through the stereo
optical system, the calibration pattern is observed
through a not-shown finder of the imaging system 13 as
shown in FIG. 17. In FIG. 17, a reference numeral 8-1
denotes an image formed through the flat mirrors 12-1
and 12-2 on the imaging system 13, and similarly a
15 reference numeral 8-2 denotes an image formed through
the flat mirrors 12-4 and 12-3 on the imaging system
13. That is, the imaging section of the calibration
device is configured so that by sizes and arrangement
20 positions of the flat platelike mirrors 12-1 to 12-4
and removal of unnecessary imaging areas by the
not-shown member for fastening, when imaging is carried
out by the imaging system 13 without any stereo optical
systems similar to the above, images 8-1 and 8-2 imaged
25 through the stereo optical system can be present in
a maximum imaging area 14 observable through the
finder. In other words, a plurality of imaging systems

are virtually formed by the stereo optical system and the imaging system 13.

Virtual frame lines 15-1 and 15-2 on the calibration pattern of FIG. 18 indicate areas of which portions on the real calibration pattern outer frames on the finder are equivalent to when the images 8-1 and 8-2 are observed in best positions in calibration pattern imaging. Conversely, if the frame lines 15-1, 15-2 are actually drawn as imaging instruction sections on the calibration pattern, and the operator can image the calibration pattern so that imaging can fully reach the boundary of the images 8-1, 8-2 on the finder, it is possible to carry out best calibration pattern imaging as a result.

Thus, as shown in FIG. 19, the calibration pattern unit of the sixth embodiment comprises a calibration pattern 5-13 where the boundary line of only the frame line 15-1 side is drawn as an imaging instruction section. That is, since stereo imaging can be carried out only for overlapped area of the frame lines 15-1, 15-2, it is only necessary to secure at least the overlapped area. In the embodiment, the boundary line of only the frame line 15-1 side is set as the imaging instruction section as it is functionally enough for only one frame line.

Accordingly, a correct calibration imaging angle can be set by paying attention to one of the images

which are imaged through the stereo optical system and passed through different optical paths.

FIG. 20 is a view showing a first modification example of the sixth embodiment of the present invention. According to the first modification example, an imaging instruction section is set by not describing a pattern outside the boundary (frame line 15-1) not to be imaged. Thus, it is possible to reduce useless pattern drawn areas.

As a second modification example of the sixth embodiment, in FIG. 21, since the outside of the boundary (frame line 15-1) is not imaged, a structure of the calibration pattern unit itself becomes a boundary. Thus, a calibration pattern side becomes minimum necessary, and it is possible to provide a calibration pattern unit excellent in portability and storage.

As shown in FIG. 22, a third modification example of the sixth embodiment is a calibration pattern unit which has a calibration pattern where the substrates of the inside and the outside of the boundary (frame line 15-1) are colored differently to constitute an imaging instruction section. Accordingly, visibility of imaging angle adjustment can be increased.

FIG. 23 is a view showing a fourth modification example of the sixth embodiment, which is a calibration pattern unit having a calibration pattern where an

imaging instruction section is described in a so-called
"register mark" form at each corner 15-1' of the
not-shown boundary (frame line 15-1). According to
the fourth modification example, a guidance function
5 can be provided by reducing an influence of information
deterioration on the original calibration pattern.

In the first to fourth modification examples of
the sixth embodiment, the imaging instruction section
is disposed for only one of the images which are
10 divided into two by the stereo optical system and
imaged. However, imaging instruction sections can be
disposed for both of these images. FIGS. 24 to 28 show
examples of imaging instruction sections disposed for
both images corresponding to the sixth embodiment, and
15 the first to fourth modification examples of the sixth
embodiment. For the fourth modification example, in
place of the configuration of FIG. 28, a configuration
of FIG. 29 may be employed.

Thus, by disposing imaging instruction sections
20 for both images, calibration pattern imaging can be
effectively carried out when more accuracy is required,
e.g., in installation of the stereo optical system with
respect to the optical system. Other operations are
the same as in the sixth embodiment, and the first to
25 fourth modification examples of the sixth embodiment
described above, and hence the explanation of them is
omitted.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details, and representative devices shown
5 and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.